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ECOLOGICAL FEATURES OF GREAT BAY, NEW HAMPSHIRE, AND A PRELIMINARY CHECKLIST OF ITS FISH

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For a number of years the writer has been collecting data on the distribution of the vertebrates of New Hampshire. Particular attention has been given to the relative number of individuals, and an attempt has been made to determine the ecological factors governing the abundance of certain species of fish.

During this work considerable variation in abundance from one time to another has been noted. The following checklist of the fish of Great Bay, New Hampshire, includes the five-year period from 1915 to 1920. The cause of fluctuations in numbers will not be analyzed in this paper, although a detailed study is being made of this problem.

The checklist includes the fish from Great Bay and Piscataqua River, above what is known as the Dover Point Bridge. This body of water is approximately seven miles long by about four miles at its greatest width, and is connected with the Atlantic Ocean at Portsmouth, New Hampshire, through the Piscataqua River. It receives a large number of streams, the most important of which is the Exeter River, Lamprey River, Oyster River, and the Bellamy River, as well as six or eight brooks of comparatively small size. The following points of ecological importance should be noted:

1. THE CHARACTER OF THE SHORE LINE

The shore line of Great Bay is exceedingly indented. Numerous rocky promontories of from 50 to 150 feet in height form an almost unbroken series of small coves and inlets. The granitic character of the shore line is such that but a small amount of silt and soil is washed into the waters of the bay. The material, therefore, which goes to make up the extensive mud flats and the silt bottoms of the coves is for the most part of a finely divided nature and has been transported from a considerable distance by the rivers and streams.

The small coves furnish an excellent habitat for such groups as *Fundulus,* the Gasterosteidae, and similar shore-inhabiting forms. In but two or three places along the shore are there extensive swamp areas, since the silting in of the small bays and inlets has not as yet proceeded to the swamp stage.

2. Types of Substrata

It would be difficult to find a greater variation of substrata than exists in this area. Many local studies have been made, which are, however, too much in detail to be included in this report. A few typical sections will serve to show the great variation in environment.

Section A.—From Cedar Point, at the mouth of the Bellamy River, due south to the deepest indention of Broad Cove. This section, approximately one mile long, includes roughly the following environmental conditions:

Beginning with Cedar Point, one passes within a few yards from a boulder-strewn shore at the high-tide mark through the sub-boulder, stone, gravel, sand, and hard clay deposits, all of which sections are more or less affected by the waves at the various tide levels. The mud-flat which follows the hard clay deposit extends out for some 250 yards and is densely covered with *Vallisneria.* This forms an ideal habitat for the *Fundulus,* pipe-fish, the eel, and the sticklebacks, which find not only protection but an abundance of food under the long-matted strands of the eel grass.

This zone, however, furnishes only temporary protection, for at low tide the greater part of it, except very small tidal pools, is exposed for one half to three quarters of an hour. *Fundulus* when caught in such a locality by the receding tide burrows into the soft mud of the pools and remains until the tide returns. This habit may also be noted in some other forms, such as the eel and occasionally in a small flounder.

By far the greater number of fish retreat with the last of the tide and find shelter in the eel grass at the edge of the mud-flats. Here congregate all of the larger predaceous fish, such as the whiting, pollock, and an occasional cod, to feed on the abundant life of the flats which temporarily collect along the margin. At the edge of the channel the flats drop off abruptly to a depth of from 25 to 45 feet to the clay bottom of the river. The surface is usually hard and smooth, being scoured by both the flow and ebb of the tide.

Over this vast expanse, which at this point is about three fourths of a mile wide, may be found numerous sculpins, flounders, and skates.

As one approaches Broad Cove there is an abrupt rise to the mud-flats, with practically a repetition of the conditions which prevail at Cedar Point. There is, however, this variation—the mud-flats of Broad Cove are never entirely exposed even at the unusual ebb tide in the fall and spring.

Section B.—From Foxes Point to Half-Tide Rock a line may be drawn northwest which, within the distance of three quarters of a mile, passes through a much greater variety of substrata. At Foxes Point one first encounters a flat of fine sand always covered with at least 3 feet of water. Here and there are to be found clumps of *Vallisneria* with an occasional boulder covered with a great variety of sessile forms.

At this point, except for one half hour at the ebb and flood, there is a swift current running first in one direction, then in the other. Just off this flat the substratum drops to about 35 feet in what amounts to a large eddy due to the nature of the ledges above and below. Here the substratum is of small stones and boulders, with occasional clumps of *Vallisneria* on the shallower slopes near the shore. In this locality may be found a greater variety of fish than in any other; nearly all species have been taken from this pool except the smaller forms such as *Fundulus* and Gasterosteidae.

Here are found cunners (*Tautogolabrus adspersus*) in the greatest abundance and, in season, the cod, pollock, frostfish, and whiting, while on the small sandy or clay patches of the bottom are flounders, sculpins, and skates.

Passing from this area outward the current becomes swifter as it flows over the rocky ledges in midstream. At places these rocks lie just below the surface, while near by they may drop to forty, fifty, or even sixty feet of water. Everywhere these rocks are covered with the long fronds of the various species of kelp, which serve as protection for numerous shrimps and crabs.

As one approaches Half-Tide Rock, opposite the mouth of Oyster River, the rocky ledges give way to a small strip of hard sand in about thirty feet of water. This area is known as the " Cod Grounds " and here collect in the late fall and early spring a considerable school of codfish ranging in weight from six to fifteen pounds. Here also may be found numerous cunner of quite large size, as well as sculpins, flounders, and an occasional skate.

From this area the substrata rises abruptly to Half-Tide Rock, which, as its name implies, is only submerged as the tide is near flood. From Half-Tide Rock to shore, a distance of about two hundred yards, the surface is strewn with boulders and clumps of *Vallisneria,* with frequent tidal pools at low tide.

Section C.—A section at any point through Great Bay proper would pass through an endless succession of mud-flats exposed at low tide. These flats are densely covered with *Vallisneria,* except in restricted areas, and are traversed by numerous channels. The channels are about thirty yards across and from ten to fifteen feet in depth with a hard, even, mud bottom. But few forms of fish are found in this area except the pipefish and flounder and wandering schools of *Fundulus,* although the channels are used as thoroughfare for those forms which pass into the various rivers emptying into Great Bay.

3. Invertebrate Life

Only the briefest summary can be given of the invertebrate life of Great Bay. The list includes all of the species common to this section, some occurring in great abundance. This is particularly true of the shore line and the eel grass beds which are literally teeming with shrimp, while the rocky bottom of the deeper portion (Section B) furnishes an environment well suited to a variety of crabs which are found in large numbers. During the spawning season great schools of *Nereis* are to be found as well as a liberal supply of other worms.

A summary of the checklist of the invertebrates, exclusive of the Protozoa, follows:

Porifera	*Cliona sulphurea.*
Coelenterata	Seven species.
Polyzoa	Two species.
Worms	Ten species, of which *Nereis* is the most abundant.
Echinodermata	Eight species.
Bi-Valve Mollusca	Seven species, of which *Mya, Modiola, Ostrea* are the most abundant.
Uni-Valve Mollusca	Fourteen species, of which *Littorina, Ilyanassa,* and *Melampus* are the most abundant.
Barnacles	*Balanus improvisus.* Very abundant on all channel rocks.
Schizopoda	*Michteimysis stenolepis,* quite abundant.
Isopoda	Four species.
Amphipoda	Twelve species.
Decapoda	Seven species.
Xiphosura	*Limulus polyphemus,* everywhere abundant.

This summary includes a total of seventy-five species, many of the most important forms from the standpoint of fish food, being very abundant.

It would seem that almost ideal food conditions exist for a great variety of fish, especially if the enormous number of *Fundulus* in any suitable locality is considered.

4. Water Conditions

A. Salinity.—The water of Great Bay is of the usual brackish type. Owing to the considerable flowage from the rivers there is marked variation in the salinity from time to time. There is a considerable drop during the spring freshets, the specific gravity reading as low as 1.000 at the surface, while in midsummer when the streams are low it may rise to 1.0245. Corresponding readings have not been taken from the Atlantic off Portsmouth Harbor except in July and August, when the average of ten readings on different dates was 1.0270.

It is unfortunate that more data could not have been secured on the oxygen concentration at different seasons and under varying tidal and flood conditions. The relation of this subject to the number and distribution of fish must be deferred to a later date.

B. Temperature.—Fluctuations in temperature of the waters in Great Bay are much greater than those of the ocean. During the winter months from the first of November to the latter part of February the temperature remains quite uniform. All of Great Bay proper, the rivers and coves freeze over, the thickness of the ice varying from a few inches to eighteen or twenty. The channels, however, in the Piscataqua River and the "tide rips" at the mouth of the bay seldom freeze over. During the summer, owing to tidal flow and to the fact that numerous ledges occur in the bottom of the channel, the temperature is quite uniform from the surface downward. In July, August, and the first part of September the average temperature is from eight to ten degrees higher than that of the Atlantic Ocean off Portsmouth Harbor. At the same time it is considerably lower than that of the rivers which flow into it.

C. Tidal Flow.—Except for from thirty minutes to an hour during the turn of the tide the water of Great Bay is in continuous movement. The tide rises on an average of about nine feet, although during the high autumn and spring tides the rise is very much greater.

As a considerable area must be covered by each incoming tide, the current at the mouth of Great Bay where it flows through the Piscataqua River to and from the Atlantic is very swift. Owing to the ledges which intercept the bottom of the channel, "tide rips" are formed with extensive whirlpools and surface agitations. The roar of the water on occasions may be heard for one half to three quarters of a mile. In other localities extensive whirlpools are formed of comparatively slowly moving water. The fish which visit this area may therefore find the greatest variety of currents as well as variation in other environmental conditions.

D. Impurities.—Owing to the proximity of several villages as well as the cities of Dover and Portsmouth, considerable sewage is poured either directly or indirectly into the waters of Great Bay. The amount of this material which actually reaches Great Bay is difficult to determine. Probably the greater percentage of solid matter is deposited on the mud-flats of the streams before they empty into the bay. At the same time the chemical constituents of the water must be affected.

5. Limiting Factors in the Distribution of Fish

The factors determining the number of species can not be fully presented in this report. It is quite evident that a radical change has taken place within recent years.

Commercial fishing, which has played such an important part in the abundance of fresh-water fish, can not be considered as a factor in this region. At no time has there been extensive commercial fishing. This applies not only to the waters of Great Bay and its tributaries, but also to the waters of the Atlantic adjacent to Portsmouth Harbor. As far as man is concerned, perhaps the chief limiting factor has been the damming of practically all the rivers emptying into Great Bay. This, as in other New England streams, reduced and ultimately stopped the run of Atlantic salmon, which have not occurred in this region for a number of years. Although the Lamprey eel is still quite abundant in certain years, the run is only a fraction of what it formerly was. Other important food species in addition to the Atlantic salmon which were formerly abundant, but which have now disappeared, are:

Common sturgeon	*Acipenser sturio*
Shad	*Alosa sapidissima*
Mackerel	*Scomber scombrus*
Bluefish	*Pomatomus saltatrix*
Striped bass	*Roccus lineatus*

This change in habits can not be due to the lack of food material, for, as has been shown, there is still an abundance of food of all kinds. A careful analysis of the factors governing the distribution in Great Bay will be given in a later paper.

6. Checklist of the Fish of Great Bay

The following is a checklist of the fish of Great Bay known to have occurred within the five-year period from 1915 to 1920:

1. **Petromyzon marinus** Linne. Lamprey.
   Occasionally common in the spring below dams at head of brackish water.
2. **Raja erinacea** Mitchill. Little skate.
   Fairly common.
3. **Anguilla rostrata** Le Sueur. Common eel.
   Very abundant at the head of brackish water. The only species of fish caught for commercial purposes.
4. **Clupea harengus** Linne. Labrador herring.
   Usually common in the colder months.
5. **Pomolobus pseudoharengus** (Wilson). Alewife.
   Very common in the spring at head of tide water.
6. **Brevoortia tyrannus** (Latrobe). Menhaden.
   Very rare.
7. **Osmerus mordax** (Mitchill). Smelt.
   Very common throughout the colder months at the head of tide water.
8. **Fundulus heteroclitus** (Linne). Killifish.
   Very abundant throughout the year.
9. **Pungitius pungitius** (Linne). Nine spined stickleback.
   Fairly common.
10. **Gasterosteus bispinosus** Walbaum. Two-spined stickleback.
    Fairly common.
11. **Apeltes quadracus** (Mitchill). Four-spined stickleback.
    Common.

12. **Syngnathus fuscus** Storer. Pipefish.
    Common along the shore.
13. **Poronotus triacanthus** (Peck). Butterfish.
    Fairly common in the spring.
14. **Tautagolabrus adspersus** (Walbaum). Cunner.
    Exceedingly abundant in summer around rocky ledges.
15. **Tautoga onitis** (Linne). Tautog.
    Very rare.
16. **Myoxocephalus aeneus** (Mitchill). Pygmy sculpin.
    Rare.
17. **Myoxocephalus groenlandicus** (Cuv.). Black sculpin.
    Very common.
18. **Myoxocephalus octodecimspinosus** (Mitchill). Long-spined sculpin.
    Very common.
19. **Hemitripterus americanus** (Gmelin). Sea raven.
    Uncommon.
20. **Merluccius bilinearis** (Mitchill). Silver hake.
    Occasional.
21. **Pollachius virens** (Linne). Pollock.
    Occasionally common.
22. **Microgadus tomcod** (Walbaum). Tomcod.
    Very common in the fall.
23. **Gadus callarias** Linne. Cod.
    Locally common in the spring and fall.
24. **Urophycis tenuis** (Mitchill). Squirrel hake.
    Found occasionally.
25. **Pseudopleuronectes americanus** (Walbaum). Winter flounder.
    Very common.
26. **Liopsetta putnami** (Gill). Smooth-back flounder.
    Common near head of tide water.
27. **Lophius piscatorius** Linne. Fishing frog.
    Very rare.